Persistent Influences of the 2002 Hayman Fire on Stream Nitrate and Dissolved Organic Carbon

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Background

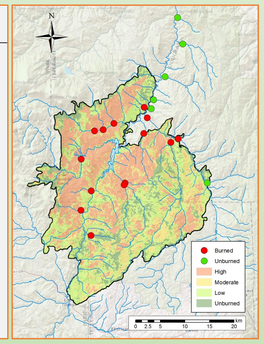
Large, high severity wildfires alter the physical and biological conditions that determine how watersheds retain and release nutrients and regulate stream water quality. Decreased plant nutrient uptake and increased mineralization of soil organic matter are the mechanisms commonly held responsible for persistent changes, though in-stream processes are also likely to play a role. Stream nitrate concentrations and export increased steadily over the course of five years following Colorado's 2002 Hayman Fire in watersheds that had extensive high-severity burning. Stream temperature and turbidity also increased in relation to the extent of high-severity burning and remained elevated throughout the initial post-fire period.

Objectives

Little is known about the long-term effects of high severity wildfires on streamwater quality. Here, we present stream N and C sampled monthly during 2015 and 2016, 13 and 14 years after the Hayman Fire, respectively. We revisit burned and unburned catchments studied the first five years after the fire, including streams sampled the year before the fire. We also evaluate longitudinal streamwater patterns across transitions in burn severity and associated with variation in post-fire riparian condition.

Study Catchments, Hayman Fire Perimeter and Burn Severity

Catchment	Catchment Area Total	Catchment Area Burned	Burned	Wildfire Severity % of Catchment Area Low	Moderate	High
	km²		%		%	
East Turkey	4.2	4.2	100	6	14	81
Wildcat	5.1	5.1	100	18	9	73
Brush	5.9	5.4	91	29	3	59
Corral	10.3	8.6	84	11	4	70
Turkey	57.8	45.4	79	40	18	20
Fourmile	20.6	15.4	74	12	10	52
Burnt Pine	9.3	5.3	58	10	2	45
West	178.6	82.1	46	21	15	10
Cabin	19.8	7.2	37	13	1	23
Wigwam	43.3	15.3	35	11	1	24
Hackett	4.3	1.4	33	25	8	0
Horse	529.8	117.7	22	10	7	5
Goose	215.3	21.5	10	3	1	6
Trout	325.9	25.5	8	3	3	1
Fern	18.6	0.1	0	0	0	0
No Name	3.8	0.0	0	0	0	0
Jenny	4.6	0.0	0	0	0	0
Sugar	34.3	0.0	0	0	0	0
Pine	35.2	0.0	0	0	0	0
Russel	6.4	0.0	0	0	0	0

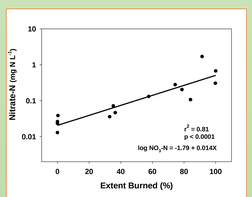


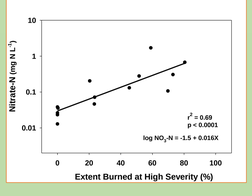
Burn Severity

High
Consumption of nearly all pre-fire ground cover & surface organic matter.

Moderate
Most (50-80%) ground cover, OM consumed. Foliage may remain in tree canopies.

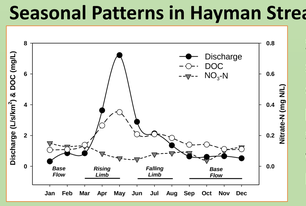
Wildfire Extent and Severity



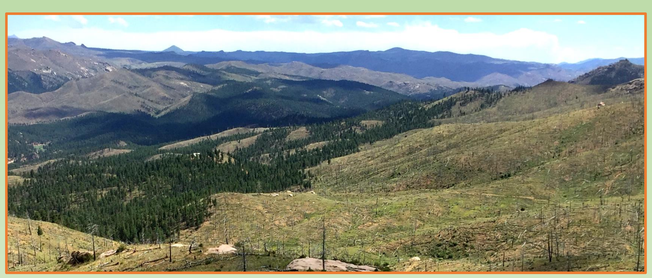


Post-wildfire stream nitrate relates to the extent of a catchment burned and the extent of high severity combustion. Catchments exceeding ~50% for either metric had roughly 10X more stream nitrate. Data are means of monthly concentrations for 2015 & 2016 water years.

Seasonal Patterns in Hayman Streams



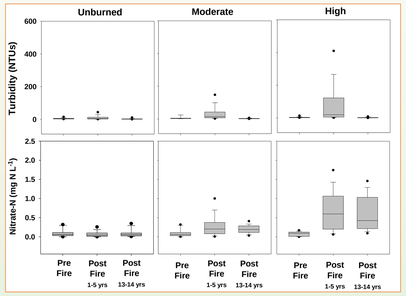
Stream discharge and dissolved organic C (DOC) peak in May with spring snow melt when nitrate (NO_3-N) is at its lowest.

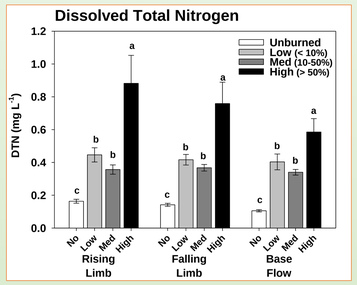


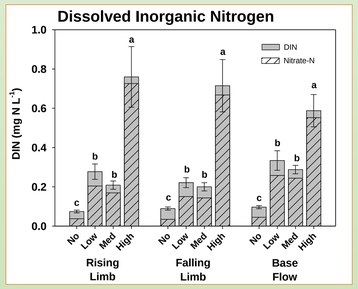
Persistent Effects

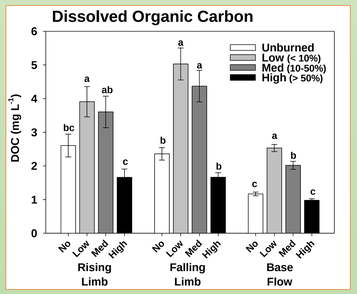
Stream turbidity and nitrate were elevated for five years after the fire in catchments with moderate and high extent of high severity wildfire.

After 14 years, nitrate but not turbidity remained elevated. There was limited attenuation of nitrate concentrations since the first post-fire period in either burn category. Nitrate remains an order of magnitude above pre-fire levels in catchments with extensive high severity wildfire.









Shifted Limitations

Much lower C:N was coupled with much higher inorganic N in severely-burned streams.

Low stream DOC may be the lasting effect of organic matter losses during the wildfire compounded by low allocthonus inputs from uplands or riparian zones.

The observed high inorganic N and low DOC may signal a switch from the N-limited conditions typical of pristine catchments to C-limited in-stream production. Initial nutrient injections indicate that only a minor amount of added N is taken up (retained) in burned streams. See ***Rhea et al. AGU Poster #169104*** for more information.

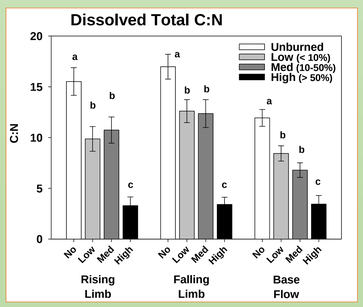
Dissolved Total Nitrogen
TDN concentration in catchments dominated by high severity wildfire was 3 - 4X higher than in unburned streams. DTN was intermediate in low and moderate extent of high severity (<50%). . Letters denote post hoc means differences.

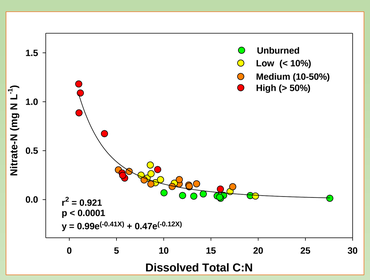
Inorganic Nitrogen & Nitrate
Nitrate represents much of the DIN and TDN in burned streams with little seasonal change.

	DIN	DTN
High	91%	85%
Mod	77%	54%
Low	70%	46%
Unburn	44%	30%

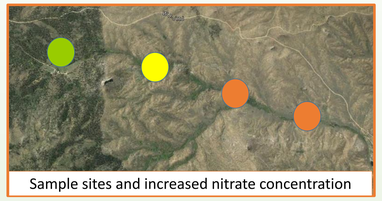
Dissolved Organic Carbon
Catchments with low to moderate amounts of high severity wildfire had roughly double the DOC concentration of unburned streams. Catchments with extensive high severity burning had the lowest DOC.

Dissolved C:N
Catchments with extensive high severity burning had consistently low C:N (~3). Low and moderate burned catchments were intermediate (8-12). Unburned streams show seasonal patterns with highest during rising limb, consistent with high spring DOC export.





Crossing the Fire Perimeter

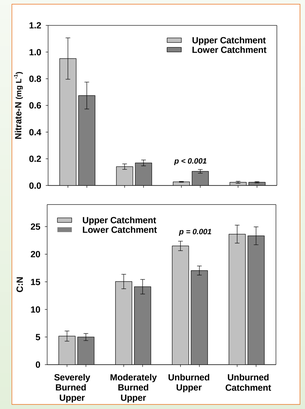


Sample sites and increased nitrate concentration

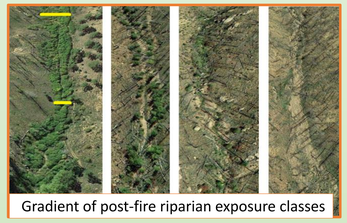
We compared stream water in upper and lower portions of burned and unburned catchments.

Streamwater did not differ significantly among upper and lower sections of totally unburned catchments or those with high or moderate severity wildfire distributed throughout the catchment.

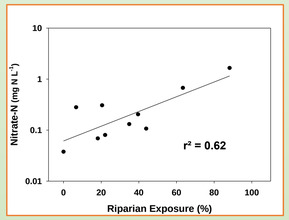
Stream nitrate differed only for streams that flowed from unburned headwaters to burned lower catchments.



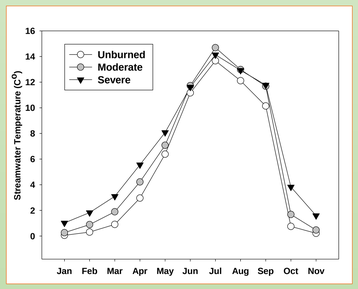
Riparian Conditions



Gradient of post-fire riparian exposure classes



Current riparian conditions are linked to stream nitrate in burned watersheds. For example, stream nitrate increases proportionally to the extent of riparian zones with low shrub cover (R^2 = 0.76).



In 2016 temperature was significantly higher in streams burned by the 2002 Hayman Fire compared to unburned streams.

Streams with extensive high severity wildfire were warmer than those with less high severity fire.

Stream temperature differed most during spring runoff (March-May), when high severity catchments were ~2C° above unburned streams.

Implications

We found few signs of watershed recovery since the initial five year post-fire period; stream nitrate, temperature and turbidity all remained elevated in extensively burned catchments, though some effects were only significant seasonally.

The persistent and high nitrate concentrations in catchments with burned headwater sections and exposed riparian zones should help prioritize restoration planting efforts and mitigate chronic, elevated nitrate export following severe wildfires.

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